Freight Demand Characteristics and Mode Choice: An Analysis of the Results of Modeling with Disaggregate Revealed Preference Data

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ABSTRACT

Considerably less research has been done on modeling freight demand with disaggregate discrete models than on modeling passenger demand. The principal reason for this imbalance is the lack of freight demand data. Freight demand characteristics are expensive to obtain and are sometimes confidential. This paper analyzes the freight demand characteristics that drive modal choice by means of a large-scale, national, disaggregate revealed preference database for shippers in France in 1988, using a nested logit. Particular attention is given to private transportation (own account transportation) and combined public and private transportation. After aggregation and validation of discrete choice models, the influence of demand characteristics on freight modal choice is analyzed. The maximum probability of choosing public road transportation takes place at approximately 700 kilometers, while that of choosing rail transportation take place at 1,300 kilometers.

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INTRODUCTION

In France, freight is increasingly transported by road, which results in a variety of negative, external effects such as congestion, pollution, and accidents. This has led public authorities to attempt to reduce its predominance. One area of interest is intercity freight modal choice and the competition between rail and road. The French Ministry of Transport, in cooperation with other French transportation research organizations, the National College of Bridge and Roads (ENPC) and the French National Research Institutes for Transport and Safety (INRETS), has for the first time developed a freight analysis system that emphasizes the modeling of freight mode choice.

These discrete-choice models permit the construction of a very general utility function incorporating many freight demand characteristics and transportation service attributes. Freight modal choice depends on transportation demand and infrastructure as well as service supply characteristics. It thus embodies a trade off between generalized transportation costs and shippers' logistical costs. On the supply side, the principal explanatory variables that have been included in previous disaggregate models are alternative-specific transportation service variables, such as transportation cost and transit time, frequency, and damage rates (Daugherty 1979, Van Es 1982, Gary 1982, Fowkes and Tweddle 1988, Widlert and Bradley 1992). However, on the demand side, few studies have attempted to systematically establish a relationship between mode choice and freight demand characteristics. The chief reason for the absence of freight demand analysis is the difficulty in collecting the necessary data, due to the great heterogeneity of firms and to questions of confidentiality and reliability of data (Ortuzar and Willumsen 1994). Thus, the influence of demand characteristics on freight mode choice has not been sufficiently understood.

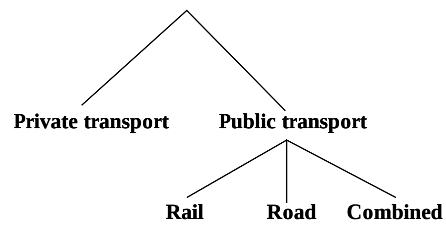
In fact, demand characteristics, such as the attributes of the shipper, the attributes of the goods to be transported, and the spatial attributes of shipments, strongly influence modal choice. Any change in these characteristics can make shippers' demands for transportation service change considerably, often leading to the choice of a new transportation mode. In order to provide a quantitative evaluation of freight demand characteristics, INRETS carried out a shippers' survey in 1988 for its freight research and development program. The survey was carried out by professional investigators who interviewed the logistics managers of industrial and commercial enterprises. The first step they took was a presurvey aimed at finding a suitable methodology for the quantification of transportation demand. The second step, the principal survey, proceeded according to a sample design that ensured representation at the national level. Selected by activities, size, and other characteristics, 1,742 industrial and commercial firms distributed in 21 regions and 20 economic sectors were requested to provide information on three shipments. The principal survey thus included 5,110 shipments. The questionnaire was comprised of three parts that dealt with 1) the characteristics of the firms, either shippers or receivers, 2) the physical characteristics of the shipment, such as type of goods, size, cost, and packaging, and 3) information about the linkages and itinerary of the shipment. The resulting database covers 51 quantitative and qualitative characteristic variables. Transportation service attributes, such as transportation time and cost, were also requested, but, unfortunately, very few shippers answered the questions for reasons of confidentiality and lack of knowledge about service attributes (Gouvernal and Hanappe 1986, Bredeloup et al. 1989). At present, the INRETS survey is the only national disaggregate revealed preference database for freight transportation in France. For this reason, this paper concentrates only on freight demand characteristics.

The purpose of this paper is to analyze how freight demand characteristics relate to and influence shippers' modal choice, using a nested logit model as an analytical tool. The contents of the paper are as follows: the second section describes the transportation mode and demand characteristic variables considered. The third section presents the results of estimating the nested logit models of modal choice. The fourth sections aggregates the results of the models, and the fifth section validates the aggregated results. The sixth section examines the marginal effects of demand characteristics and transportation services on mode choice. The final section presents our conclusions.

TRANSPORTATION MODES AND FREIGHT DEMAND CHARACTERISTICS

The various modes covered by the INRETS shippers' survey can be grouped into two transportation modes: private road transportation (i.e., own account transportation) and public (purchased) transportation. Public transportation includes rail, road, inland waterways, air transportation, maritime, pipelines, and intermodal transportation. Private transportation has long been regarded as a means of transporting goods over short distances but not as competitive with the other transportation modes over long distances. However, with the development of integrated logistic systems, public transportation modes must compete with private transportation to create added value for shippers in the movement of goods. In this new system, shippers can opt for private transportation even for long distance shipments, leading to an additional increase in road traffic. In view of the importance of the private versus public transportation choice, this paper will first deal with the modal choice between private and public transportation and then with the choice between rail, road, and combined transportation. Figure 1 represents this process.

FIGURE 1 Nested Multinominal Logit Model Structure



Two situations were considered rail transportation: when the departure or arrival point is a rail branch line and when there is road plus rail with passage through railway stations. Only the railroad traffic through CNC or Novatrans (two combined transportation companies in France) loading yards were considered. In total, the data used include 3,473 observations, which can be broken down as follows: 1,421 observations for private transportation; 2,052 observations for public transportation, of which 1,866 observations relate to road transportation, 123 are rail transportation, and 63 are combined transportation.

We can divide available freight demand characteristics into three types: a firm's (shipper's or receiver's) characteristics, goods' physical attributes, and the spatial and flow characteristics of shipments. A firm's characteristics include the nature of the firm, such that in this category we find type of firm (for example, factories, shopping centers, or warehouses); the firm's structure (small, nationwide, or worldwide); the firm's location (for example, the accessibility to rail branch lines and highways); and the firm's size, represented by the number of employees. A firm's own transportation facilities closely relate to its transportation demand and are also an important factor in its modal choice. In addition, a firm's information system strongly influences its logistic practices and plays an increasingly important role in its transportation decisions. All of these characteristics are represented by dummy variables and are taken as long term factors for modal choice because changes in these characteristics will be made at the strategic, long term level, rather than at the day-to-day decision-making level.

The next type of demand characteristic is the attributes of the goods to be transported, such as type of product, weight, value, and packaging. The type of product includes a wide range of categories, for example, foodstuffs and fodder, machines and metal articles, transportation and agricultural materials. Packaging is generally either parcels and pallets or tanks, containers, and cases.

Finally, frequency, distance, origin, and destination of a shipment are its spatial distribution and physical flow attributes. Transportation distance was calculated from the 1988 Information System for Freight Transport (SITRAM) database of the French Ministry of Transport. Destinations include all French regions and many European countries, such as Italy, Spain, Belgium, Switzerland, Germany, and the Netherlands. Since these characteristics can change in a short time according to market demand, they are taken to be short term factors for modal choice.

The various long and short term characteristics can be summarized as follows:

- Long term factors: the firm's nature, size, location, information system, structure, and trucks owned by the firm
- Short term factors: physical attributes of goods, physical flow attributes, and the spatial distribution characteristics of shipments.

MODEL SPECIFICATION AND EMPIRICAL FINDINGS

The multinomial logit model (MNL) has often been used to model freight modal choice. However, because the unobserved attributes of road, rail, and combined transportation modes viewed as public transportation are likely to be correlated, the independent and identically distributed (IID) assumption of the multinomial logit model will likely not be satisfied if we define the choice set as private transportation, road, railway, and combined transportation. It is probably more accurate to represent the decisionmaking process of modal choice for shippers with a nested MNL model: the higher level modal choice is between private and public transportation, and the choice among road, railway, and combined transportation is within the public mode.

First Level: The Choice Between Road, Rail and Combined Transportation

$$P_n\ (y{=}road){=}\frac{\exp(V_{road})}{1+\exp(V_{road})+\exp(V_{comb})} \quad (1.1)$$

where

V_{road} and V_{comb} are utility functions for road transportation and combined transportation.

Second Level: the Choice Between Private and Public Transportation

$$P_n\ (y{=}public){=}\frac{\exp(V_{public}+V'_p * \mu_p)}{1+\exp(V_{public})+V'_p * \mu_p)} \quad (1.2)$$

where

- p represents public transportation.
- μ_p is the scale parameter for public transportation.
- V_{public} is utility function for public transportation.
- V'_p represents the log-sum variable of the nested logit model and can be written as:

$$V'_p = \ln[\exp(V_{road}) + \exp(V_{comb}) + 1]. \quad (1.3)$$

Hence, the modal choice probability for public road transportation compared with private transportation is :

$$P_n\ (y{=}road){=}\frac{\exp(V_{road})}{1+\exp(V_{road})+\exp(V_{comb})} * \frac{\exp(V_{public}+V'_p * \mu_p)}{1+\exp(V_{public})+V'_p * \mu_p)} \quad (1.4)$$

Estimation results on the first level of choice between road, rail, and combined transportation are presented in table 1, where the referenced alternative is rail transportation. The t statistics in parentheses indicate that most of the variables are statistically significant, although for the choice between road and rail, variables such as shipment size, shipment frequency, and shipment to Paris, they are less significant, and for the choice between combined transportation and railway, the variables such as warehouse and shipment in barrels-tank are less significant. The signs of variables indicate shippers' preferences for mode choice. We note that long distance transportation, shippers and receivers located on rail branch lines, large firms, shippers with their own smaller sized trucks, and shipments from Paris are favorable for rail transportation. Conversely, shippers who package in pallets and shippers with information systems prefer other modes to rail transportation. For combined transportation, there are positive effects for long distance transportation, shipments to Paris, large firms, and shippers with rail branch lines. However, for large size shipments, shipments to foreign countries, and shippers near highways, less combined transportation tends to be favored. On the other hand, for short distance transportation, shippers with information systems such as EDI, near highways, or with shipments packaged in pallets and in tanks favor road transportation. In contrast, large companies, shippers and receivers near rail branch lines, and shippers with their own small trucks tend to favor transportation by road less.

TABLE 1 Modeling Results for the First Level Choice				
Explanatory variable	**Road vs. rail**[1]		**Combined vs. rail**	
Constancy for road	4.76	*(16.4)*		
Constancy for combined transport			–1.22	*(–2.4)*
Distance	–0.0017	*(–5.3)*	0.003	*(5.0)*
Shipment size	0.00000319	*(–1.2)*	0	*(–2.8)*
Shipment frequency	0.00000445	*(–1.7)*		
Number of employees	–0.0005	*(–3.6)*		
Warehouse	–1.3	*(–3.8)*	–1.26	*(–1.7)*
Shopping center	–0.832	*(–2.8)*		
Shipper with information system	1.82	*(2.8)*	1.65	*(1.9)*
Shipper near highway			–0.995	*(–2.6)*
Shipper with rail branch line	–0.52	*(–2.5)*		
Receiver with rail branch line	–1.2	*(–4.9)*	–0.977	*(–2.0)*
Package in barrels–tank	2.25	*(2.5)*	1.96	*(1.4)*
Package in tank container	1.46	*(2.7)*		
Pallets	0.799	*(2.6)*	1.14	*(2.5)*
Shipment in a circuit	2.02	*(2.0)*		
Shipment to foreign country			–4.6	*(–3.7)*
Shipment to Paris	–0.445	*(–1.6)*	0.786	*(1.9)*
Shipment from Paris	–0.842	*(–3.3)*	–0.9	*(–1.8)*
Shipper with own wagon	–0.0282	*(–2.5)*		
Shipper with own truck(<3t)	–0.945	*(–3.7)*	–0.873	*(–2.1)*
Shipper with own truck (3–6t)	–1.14	*(–4.1)*	–0.884	*(–1.8)*
Log-likelihood of complete model		*–585.99*		
Log-likelihood of restraint model		*–742.93*		
McFadden's pseudo-R2		*0.21*		
Percentage of correct prediction		*85.76*		

[1] Numbers in parentheses represent *t*-statistics

Estimation results on the second level of choice between private (in house) and public (purchased) transportation are presented in table 2 where the referenced alternative is private transportation. All of the variables are significant as indicated by their *t*-statistics. In addition, the scale parameter of the log-sum term is equal to 0.272 and is therefore between 0 and 1. This confirms that a nested logit model should be used for this case and that a simple MNL formulation would be incorrect. As for the shippers' preference for mode choice, the signs of variables indicate that for long distance transportation, high frequency shipments, both shipper and receiver located on a rail branch line, shipment in parcel, worldwide companies, manufacturing products, and metal industries public, transportation is preferred. On the other hand, for warehouse receivers, shipment in a circuit, small companies, shippers with own truck, food, and agricultural products, private transportation tends to be favored.

We further discuss the importance of demand characteristics for mode choice in a later section by analyzing the marginal effects of demand characteristics.

Aggregation of the Results

The ultimate objective of modeling is to forecast and measure the sensitivity of transportation demand to transportation policy and economic conditions. However, for purposes of government policy-making, aggregate behavior is of greater interest than the behavior of any individual firm.

TABLE 2 Modeling Results for the Second Level Choice

Variable	Public vs. private[1]	
Constancy	–1.498	*(–6.3)*
Distance	0.005	*(20.3)*
Shipment frequency	0.00000915	*(5.1)*
Receiver is a warehouse	–0.431	*(3.0)*
Shipper with rail branch line	0.533	*(4.5)*
Receiver with rail branch line	0.605	*(4.1)*
Parcel	0.761	*(7.1)*
Shipment in a circuit	–2.45	*(–12.6)*
Small firm	–0.413	*(–2.9)*
Worldwide company	0.676	*(5.1)*
Shipper with own truck (6–17t)	–1.825	*(–12.6)*
Shipper with own truck (>17t)	–1.983	*(–16.1)*
Manufacturing products	0.338	*(2.9)*
Foods	–0.295	*(–2.0)*
Metal	0.642	*(2.0)*
Agricultural products	–0.565	*(–2.0)*
V'_p	0.272	*(5.4)*
Log-likelihood	–1,363.725	
Numbers of observation for public transport (1)	1,967	
Number of observation for private transport (2)	1,317	

[1] Numbers in parentheses represent *t*-statistics

Therefore, the aggregation of disaggregate forecasts from discrete models is indispensable. The simplest method is direct aggregation or the naïve method. In this case, the average values for all explanatory variables are calculated, and then the aggregated choice probabilities are estimated with these average values. This approach is prone to aggregation bias when applied to nonlinear models. For this reason, researchers have developed approximate methods, such as the TALVITIE method and the market segmentation method, in order to find the best combination of calculation cost and precision of results (Ben-Akiva and Lerman 1985).

The TALVITIE method constructs the second order Taylor expansion of a choice probability function as an approximation of the exact choice probability. This expression is then used to compute the aggregate choice probabilities at the mean value of the explanatory variables. The result of the TALVITIE method is equivalent to the result of the naïve method, plus an error term, which depends jointly on the sample and the result of naïve method. Unfortunately, it is not clear that the TALVITIE method provides more precise results than the naïve method with an appropriate error term.

The market segmentation method is a logical extension of the naïve method. It divides the given market into several homogeneous groups so that error variance is minimized in each group and is maximized between groups. Then the direct (naïve) method is applied to each defined segment. The aggregate result is finally obtained by taking the average value of probabilities for each market segment, weighted by the market shares of each given market segment. This method reduces the aggregation bias produced by the use of average values, due to the fact that the data's characteristics in each segment are not significantly different.

Each of these methods has been used in passenger transportation modal choice analyses. For the aggregation of freight transportation demand, there have been no special methods developed, and few case studies exist. From existing empirical applications for passenger transportation, it appears that the most commonly used methods are sample enumeration and market segmentation. Other methods, such as the TALVITIE and the naïve methods, are very seldom used. Assuming that commodities' logistical families determine their transportation demand, we believe that market segmentation is a satisfactory method for the aggregation of freight forecasting results

The first stage of the market segmentation method is to select variables that can explain shippers' behavior and to determine the number of categories to be created for each selected variable in order to minimize the variability of representative utility (i.e., the bias of aggregation). Clearly, there is a trade off between the reduction of bias and the complexity of segmentation. Additionally, preference is given to segments corresponding to existing aggregate information so that the forecast results can be compared with observed data.

In France, SITRAM and the Database for Road Freight Transportation (TRM) are the government's two databases for freight transportation.

Important variables for segmenting the market include the type of goods (Nomenclature pour les Statistique de Transport (NST) classification), distance, and packaging. Using the SITRAM database, we calculated the average transportation distance and the modal share for each type of product. In general, only products transported over long distances (more than 150 kilometers) with a relatively low rail share have been thought to have the potential for shifting from road to rail in France. The following products make up 65% of total traffic:

- Foodstuffs and fodder (NST 1)
- Basic chemical products (NST 8)
- Transportation and agricultural material (NST 9A)
- Machines and metal articles (NST 9B)
- Other manufactured products (NST 9C)

THE VALIDATION OF MODELS

The logical step following model development is model validation. Model validation has been defined as the process that assures that a model describing a phenomenon does so adequately for the model's intended use (Miser 1993). Three types of validation have been distinguished: technical, operational, and dynamic (Gass 1983). Technical validation refers to the use of the correct kind of data, assumptions, and relations in the model, along with method. This is also referred to as internal validation (Taylor 1983). Operational validation concerns the assessment of the kind and the importance of errors produced by the model in comparison with reality (i.e., how the model represents reality). Finally, dynamic validation is concerned with determining how well the model predicts over different time periods. Operational and dynamic validation are also referred to as external validation (Taylor 1983).

In this paper we test the operational validity of the model. Operational validation provides information about the practicality of the model and shows the difference between reality and the results of the model. This requires a database that describes an actual situation. The database used here is SITRAM; in it the modal shares are represented by tons or tons-kilometers. But, the forecasted probabilities or modal shares obtained from our models are expressed in terms of the number of shipments. Therefore, in order to compare the forecasted results with actual results, the first step is to transform the modal shares in numbers of shipments to the modal shares in tons or ton-kilometers. To do this, we have used the following formulas:

where

$$P(i)_T = \frac{P(i)_E * W(i)}{\sum_{j=1}^{J} P(j)_E * W(j)} \tag{2.1}$$

or

$$P(i)_{TKM} = \frac{P(i)_E * W(i) * D(i)}{\sum_{j=1}^{J} P(j)_E * W(j) * W(i)} \tag{2.2}$$

- $P(i)_T$ is choice probability in tons for mode *i*.
- $P(i)_{TKM}$ is choice probability in ton-kilometers for mode *i*.
- $P(i)_E$ is choice probability expressed in percentage of shipments for mode *i*.
- $W(i)$ is average weight of shipment for mode *i*, and
- $D(i)$ is average distance for mode *i*.

The average weights and average distances are obtained from SITRAM. The aggregated shipment shares are predicted by our models. By combining them, we obtain mode share in tons and ton-kilometers for each segment, which can then be compared with actual statistics. Table 3 presents the comparison of mode share in tons. The forecast error for foodstuffs and fodder and for chemical products is the largest, most likely because there are fewer observations of these types of goods in the sample. In general, we found that the forecast results for each segment obtained this way are more precise than those derived by the direct aggregate method.

MARGINAL EFFECTS OF DEMAND CHARACTERISTICS

The marginal effects of the explanatory variables on modal choice behavior for dummy variables have means that are fractions.

The elasticities of choice probabilities between road, rail, and combined transportation with respect to explanatory variables shown in table 4 enable us to analyze the role of demand characteristics in mode choice. For the choice between road and rail transportation, transportation distance,

TABLE 3 Comparison of Forecasted and Actual Results (percent)

Segments	Private transport Estimation	Private transport SITRAM	Private transport Error	Public road Estimation	Public road SITRAM	Public road Error
Foodstuffs and fodder	68.17	61.73	6.44	29.18	33.51	–4.33
Chemical products	31.66	31.81	–0.15	65.16	59.30	5.86
Other manufactured products	37.27	37.44	–0.17	53.35	52.53	0.82
Agricultural and transportation material	48.03	47.12	0.91	51.11	51.59	–0.48
Machines and metal articles	33.43	34.10	–0.67	63.82	60.75	3.07
TOTAL	56.25	59.33	–3.08	38.12	34.90	3.22

company size, information system, rail branch line, use of pallets, and shippers owning trucks play the most important roles. Among these factors, only information system and pallets show preference for road transportation. For the choice of combined transportation, transportation distance, shipment size, shipment to a foreign country, shipper proximity to a highway, shipment to Paris, company size, and rail branch line are very important factors. For long distance shipments and shipments to Paris, combined transportation is especially preferred.

To analyze shippers' modal choice behavior among private transportation, road, rail, and combined transportation, the partial derivatives of probability with respect to the explanatory variables must be calculated. It can be expressed in the following formula (Liao 1994).

$$\left(\frac{\partial P_1}{\partial x}\right)P_{2/1} + \frac{\partial P_{2/1}}{\partial x} + \left(\frac{\partial P_1}{\partial x}\right)\left(\frac{\partial P_{2/1}}{\partial x}\right) \qquad (3.1)$$

Using equation 3.1, we can estimate elasticities, and the results are found in table 5. Because companies generally use their own trucks for the deliveries of goods and call on public transportation for the supply of goods for production, the shipper's own large trucks play an important role for the initial choice between private and public transportation. Furthermore, companies owning trucks of more than 17 tons strongly prefer private transportation, although this tendency is diminished for long distance transportation.

We also found that transportation distance, shipment in parcel or in a circuit, and the accessibility of railways' infrastructure strongly influence the choice between private and public transportation. For example, long distance shipments or shipments packaged in parcels are more likely to be shipped by public transportation, but shipments in a circuit rely heavily on private transportation.

TABLE 4 Elasticities of the Choices Between Road, Rail, and Combined Transportation (at means)

Variable	Road	Combined	Rail
Distance	–0.038	1.807	0.619
Shipment size	0.004	–0.596	0.025
Shipment frequency	–0.002	0.048	0.048
Number of employees	–0.007	0.154	0.154
Warehouse	–0.002	–0.00019	0.059
Shopping center	–0.002	0.050	0.050
Shipper with information system	0.005	–0.009	–0.141
Shipper near highway	0.003	–0.293	0.003
Shipper with rail branch line	–0.006	0.146	0.146
Receiver with rail branch line	–0.007	0.028	0.181
Package in barrels–tank	0.003	–0.008	–0.079
Package in tank container	0.003	–0.074	–0.074
Pallets	0.005	0.076	–0.161
Shipment in a circuit	0.003	–0.073	–0.073
Shipment to foreign country	0.003	–0.380	0.003
Shipment to Paris	–0.004	0.194	0.068
Shipment from Paris	–0.004	–0.012	0.113
Shipper with own wagon	–0.001	0.014	0.014
Shipper with own truck(<3t)	–0.006	0.007	0.172
Shipper with own truck (3–6t)	–0.004	0.022	0.114

TABLE 5 Elasticities of the Choice of Four Modes Considered (at means)

Variable	Private	Road	Combined	Rail
Distance	–0.995	0.449	1.782	0.924
Shipment frequency	–0.068	0.030	0.079	0.079
Receiver is a warehouse	0.033	–0.016	–0.016	–0.016
Shipper with rail branch line	–0.098	0.040	0.205	0.205
Receiver with rail branch line	–0.056	0.020	0.056	0.216
Parcel	–0.243	0.116	0.116	0.116
Shipment in a circuit	0.221	–0.103	–0.159	–0.159
Small firm	0.039	–0.019	–0.019	–0.019
Worldwide company	–0.090	0.043	0.043	0.043
Shipper with own truck (6–17t)	0.169	–0.081	–0.081	–0.081
Shipper with own truck (>17t)	0.304	–0.145	–0.145	–0.145
Manufacturing products	–0.060	0.029	0.029	0.029
Foods	0.028	–0.013	–0.013	–0.013
Metal	–0.012	0.006	0.006	0.006
Agricultural products	0.013	–0.006	–0.006	–0.006

Finally, we considered the changes in choice probabilities as functions of continuous variables, such as transportation distance, shipment size, and shipment frequency. In general, an increase in transportation distance and shipment frequency tends to raise the shares for rail and combined transportation. However, with increasing shipment size, the probability of choosing combined transportation diminishes, while that of rail transportation increases.

Transportation distance is a very important factor in mode choice. Figure 2 shows the evolution of choice probability for transportation distances between 100 and 3,000 kilometers. For short distance transportation, road transportation is the dominant mode and has little competition from other modes. On the other hand, the shares of rail, road, and combined transportation depend strongly on transportation distance at distances longer than 1,000 kilometers. For example, if the distance is less than 300 kilometers, the traffic is shared between private truck transportation and public road transportation. The maximum probability of choosing public road transportation takes place at approximately 700 kilometers, but that of choosing rail transportation occurs at 1,300 kilometers. Combined transportation becomes dominant if transportation distance is more than 1,400 kilometers.

We can also examine the joint effects of transportation distance and shipment destination. Figure 3 shows the probability of choosing combined transportation versus railway with respect to transportation distance for an international or national shipment. We can see that for long dis-

FIGURE 2 The Effect of Transport Distance on Mode Choice

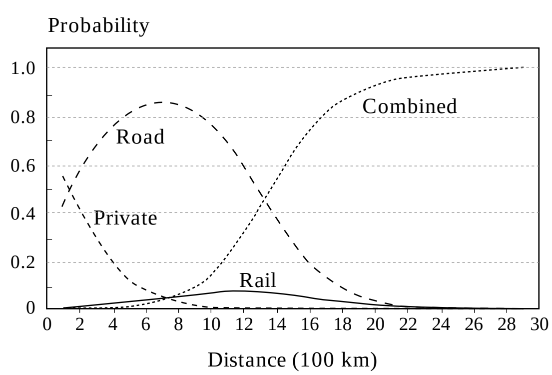
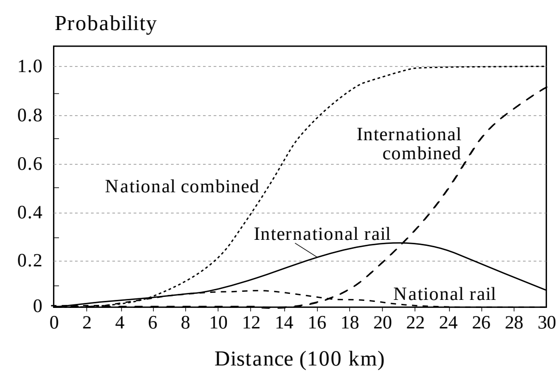


FIGURE 3 The Effect of Distance on the Mode Choice for National and International Shipments



tance international shipments, rail plays a more important role than for long distance intranational shipments. Furthermore, if the shipment distance is less than 1,500 kilometers, international shipments tend not to use combined transportation.

CONCLUSION

In this study, we used French freight demand survey data to estimate a disaggregate, discrete choice model. Using elasticities of choice probabilities, we analyzed how demand characteristics influence the choice between transportation on a shipper's own account versus purchased road, rail, and combined transportation. We found that transportation distance, the shipper's accessibility to transportation infrastructure, the shipper's own transportation facilities, and shipment packaging (pallets and parcel) are the critical determinants of the demand for rail and combined transportation. For long distance nationwide transportation, combined transportation may be an important mode, but for long distance international transportation, the existing quality of service of combined transportation apparently fails to satisfy shippers' needs, and conventional rail transportation plays a significant role.

This study's results point to the need for careful and systematic analysis of the changes in firms' logistical systems for predicting traffic mode split and for evaluation of the effects of transportation infrastructure decisions on the modal structure of freight traffic. Much greater detail is needed concerning the interactions between firms' logistical decisions, their shipment demands, and the characteristics of alternative transportation modes. We hope that this study provides a starting point for these issues and their influence on freight modal choice.

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